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THE QUEENSLAND JOURNAL OF AGRICULTURAL SCIENCE

MARCH, 1958.

VOL. 15. No. 1.

STUDIES ON VARIETAL RESISTANCE TO STEM ROT (*Phytophthora vignae* Purss) IN THE COWPEA

By G. S. PURSS, B.Sc.Agr., Pathologist, Plant Pathology Branch, Division of Plant Industry.

SUMMARY.

The reaction of local and introduced cowpea varieties and some other legume species to stem rot (Phytophthora vignae) in pot tests, nursery plots and field trials is described.

On the basis of their reaction the varieties may be placed in three groups. The first includes those such as Poona and Reeves which are susceptible under all conditions of testing. The second includes Malabar, Giant and some others which are susceptible in pots but show variable reaction under other conditions. The varieties in the third class, which exhibit complete resistance, include Blackeye 5 and Havana.

It is shown that the resistance to stem rot possessed by Blackeye 5 is dominant over the susceptibility possessed by Poona.

Evidence is produced to show that control of the disease can be achieved by the use of resistant varieties either introduced from overseas or synthesised by plant breeding.

I. INTRODUCTION.

In an earlier paper (Purss 1957) a new disease of cowpeas (*Vigna sinensis* (L.) Endl. ex Hassk.) known as stem rot and the causal organism (*Phytophthora vignae*) were described. This paper is devoted to studies of the reaction of various cowpea varieties and other leguminous plants to the disease.

Control of soil-borne diseases such as stem rot is best achieved by the use of resistant varieties. In the case of cowpeas, which are used primarily as a green manure or fodder crop, the use of more expensive control measures could not be contemplated.

The two most popular varieties, Poona and Reeves, are both susceptible to the disease. Other cowpea varieties developed locally or introduced from other countries by the Plant Introduction Section of C.S.I.R.O. have therefore been collected and subjected to disease testing. In addition, other species of legumes considered to be of some potential importance under tropical and subtropical conditions have been screened.

This work has been carried out under three different sets of conditions—pot testing, nursery plots and field trials.

II. POT TESTING.

The technique employed here was identical with that used in the pathogenicity tests described in the earlier paper, where inoculation was done below ground level. Briefly, seedlings were raised in 7 in. earthenware pots and when

Table 1.

REACTION OF COWPEA VARIETIES TO STEM ROT IN POT TESTS AND NURSERY PLOTS.

Variety.	C.P.I. No.	Source.	Pot Tests.		Nursery Plots.	
			No. of Plants Inoculated.	Percentage Infection.	No. of Plants Germinating.	Percentage Infection.
Arlington ..	9,256	Oklahoma ..	19	100	46	94
Bayo	12,149	Cuba	8	100	24	91
Black	..	Local	9	100	20	100
Black	9,254	Oklahoma ..	6	83	19	100
Blackeye 5 ..	12,377	California ..	49	0	79	0
Blackeye 7 ..	12,378	California ..	6	100	9	88
Brabham ..	..	Local	36	100	18	63
Brabham ..	9,249	Oklahoma ..	6	100	13	100
Buff	9,247	Oklahoma ..	23	61	23	33
Carito	12,150	Cuba	2	100	3	100
Chinese Red ..	9,259	Oklahoma ..	40	0	45	2
Cowpea No. 3 ..	10,753	U.S.S.R. ..	19	90	22	66
Cristaudo ..	..	Local	73	63	109	46
C 419	12,111	India	22	100	86	26
C 442	11,043	India	4	100	16	73
C 521*	11,044	India	18	66	9	22
Early Cowpea ..	11,384	Gold Coast ..	8	60	10	40
Early Giant ..	..	Local	28	100	83	76
Early Red ..	9,245	Oklahoma ..	11	100	10	40
Giant	..	Local	38	95	94	29
Groit	..	Local	45	100	80	81
Groit	9,260	U.S.A.	4	75	5	60
Iron	5,984	Texas	11	55	15	0
Iron	9,248	Oklahoma ..	22	64	71	38
Local Tanganyika	8,521	Tanganyika ..	12	50	34	48
Local Zanzibar	8,520	Tanganyika ..	8	63	15	66
Nigro*	12,148	Cuba	17	0	19	0
Polon Prolific V4	9,322	Ceylon	3	100	8	38
Poona	..	Local	82	100	200	100
Reeves	..	Local	66	100	266	90
Rojo*	12,153	Cuba	28	0	54	2
Soutter	..	Local	36	97	139	50
Tabora 2 ..	8,522	Tanganyika ..	10	70	23	34
Victor	..	Local	36	92	81	98
Victor	9,246	Oklahoma ..	8	100	38	100
V 248	9,323	Ceylon	2	100	20	95
White Crowder..	9,252	Oklahoma ..	12	40	11	27
34C361	9,432	South Africa ..	115	93	150	65
37C6	8,086	South Africa ..	21	100	39	70

* C.P.I. numbers 11044, 12148, and 12153 have been renamed Malabar, Santiago and Havana respectively by Australian authorities.

approximately four weeks old were inoculated with *P. vignae* growing on potato dextrose agar. Small cubes of the inoculum ($\frac{1}{4}$ in. square) were placed against the uninjured stems just below ground level and covered with soil. The pots were kept well watered. This technique proved highly effective but to obtain consistent results testing had to be confined to the warmer months of the year.

The number of plants of each variety used was not constant because of the variable germination of the material. The shortage of seed prevented any replication in most of the varieties, but the susceptible Poona was used at check points throughout to give an index of disease distribution. This variety was completely susceptible in these tests. Where possible, the work was conducted in a glasshouse. At other times humidity was maintained by the use of frames erected over the pots and covered with transparent plastic sheeting.

Over 200 varieties and strains have already been screened in this way and a further 300 varieties are in the process of being examined. It would be of little value to list the reaction of all varieties, as the majority were unnamed lines from overseas. The reaction of most of the named varieties appears in Table 1.

The reaction of various other legumes to the causal organism of the disease has also been determined under pot conditions. Most of these legumes have a potential value in a tropical or subtropical environment. The velvet bean,

Table 2.

REACTION OF VARIOUS LEGUME SPECIES IN POT TESTS.

Legume Species.	Variety.	No. of Plants Inoculated.	Percentage Infection.
Cajanus cajan (L.) Millsp. (Pigeon pea) ..	..	10	0
Calopogonium mucunoides Desv. (Calopo) ..	..	11	0
Glycine javanica L.	..	10	0
Glycine max (L.) Merr. (Soybean)	Gaton	11	0
	Avoyelles ..	6	0
	Otootan ..	7	0
Medicago sativa L. (Lucerne)	..	11	0
Mucuna spp. (Velvet bean)	Sommerset ..	8	0
	Black	7	0
	Mauritius ..	..	..
Phaseolus lathyroides L. (Phasey bean)	..	11	0
Phaseolus mungo L. (Mung bean)	..	10	0
Phaseolus vulgaris L. (Bean)	Black Beauty ..	10	0
	Brown Beauty..	10	0
Pisum arvense L. (Field pea)	..	11	0
Pueraria phaseoloides (Roxb.) Benth. (Puero) ..	..	7	0
Vicia sativa L. (Common vetch)	..	13	0
Vigna sinensis (L.) Endl. ex Hassk. (Cowpea) ..	Poona	10	100
	Snake bean ..	18	100

for instance, is used as a green manure crop in place of cowpeas in some Queensland canefields. The result of inoculating these legumes appears in Table 2.

The results of these tests indicated that very good resistance to the disease was present in at least four varieties of cowpea—Blackeye 5, Havana, Santiago and Chinese Red. Of the species of legumes tested, only *Vigna sinensis* was susceptible to the disease.

III. NURSERY PLOTS.

In early field trials there were indications that differences between pot reaction and field reaction to stem rot could be expected. In an effort to simulate severe field conditions, nursery plots were instituted. For these plots, rows were opened up 1 foot apart and in these were buried the remains of infected plants collected either from pot tests or from diseased fields of cowpeas. The seed of the varieties being tested was then placed in these rows. This close planting gave ideal conditions for the development and spread of the disease. The plots were kept constantly moist.

Seed of most varieties was in short supply and replication had to be dispensed with. However, the susceptible Poona was sown in rows in such a pattern that every variety being tested was adjacent to it. This variety died out in all plots as a result of stem rot infection, indicating an even distribution of the disease in the nursery.

Fig. 1.

Nursery Plots. Two centre rows of Blackeye 5 bordered by rows of Poona.

Results of the nursery plot testing appear in Table 1. The indications from these tests were that certain varieties such as Malabar and Giant, while susceptible in pot tests, possessed considerable resistance in nursery plots. Other varieties, such as Blackeye 5 and Santiago, which were resistant in pots were equally resistant in the nursery. In Fig. 1 two rows of Blackeye 5 can be seen growing healthily, while on each side the rows of Poona are badly affected by the disease.

IV. FIELD TRIALS.

These were conducted every season from 1952-53 until 1956-57. The object was to test varieties under conditions prevailing in the field rather than in the artificial conditions of the glasshouse or disease nursery. The trials were planted in almost all cases on "infested" soil—that is, on soil that had carried a crop infected with stem rot during the previous season. The varieties used during the course of these field trials have changed to some extent as susceptible lines were discarded and seed of resistant lines became available.

(1) 1952-53 Season.

During the 1952-53 season two trials were conducted in the Fassifern Valley. The first one was laid down at Fraserview as a grazing trial, but with the outbreak of stem rot it was possible to rate the susceptibility of the varieties to this disease. No cowpeas had been grown on this paddock for at least 10 years, although the crop was commonly used on the property. It can be assumed that the inoculum level in this area was low. The trial was replicated in four blocks.

The second trial was a variety trial planted at Teviotville on soil which was said to have carried an infected crop during the previous season. Restricted seed supplies of most varieties permitted only two blocks, with single-row plots 1 chain long, to be sown.

Table 3.

Results of Stem Rot Resistance Trials, Fraserview and Teviotville, 1952–53 and 1953–54. (Expressed as Percentage of the Total Number of Plants that became Affected.

Variety.	Fraserview 1952–53.	Fraserview 1953–54.	Teviotville 1952–53.	Mean.
Poona	60	90	95	81·7
Reeves	37·5	83·75	92	71·1
Cristaudo	0	36·25	19	18·4
C.P.I. 9432 ..	6	53·75	67	42·3
Giant	..	11·9	10	10·9
Groit	..	..	90	90
Soutter	..	..	80	80
Brabham	..	..	87	87
Black	..	98·75	..	98·75

Counts were made on random quadrats in each case and the results appear in Table 3.

The results of these two trials, coupled with glasshouse figures, indicated that Giant and Cristaudo, two varieties available commercially, possessed good field resistance while the remainder of the varieties were of little value. The stand produced by Cristaudo in the first trial is shown in Fig. 2.

Fig. 2.

The Cristaudo Variety of Cowpea Growing on Infested Soil.

(2) 1953-54 Season.

In the 1953-54 season a further trial was conducted at Fraserview on the site used for the grazing trial during 1952-53. The plots used were 1½ chains long and 14 yards wide and the seed was broadcast by hand. Disease incidence was assessed by using random quadrat counts. The results appear in Table 3.

It is interesting to record that in the variety Cristaudo, of the 36·25 per cent. of plants finally infected with stem rot, 35 per cent. died in the seedling stage. This was not the case with the other varieties, where infection was spread over the life of the plants. It will be noted that while Giant maintained its resistance as the infection potential increased, Cristaudo did not.

(3) 1954-55 Season.

In the 1954-55 season a trial was conducted in the experimental area at Brisbane. This was designed firstly to compare a number of "strains" of the varieties Cristaudo and Giant obtained from various sources, and secondly, to try some of the more promising introductions, already glasshouse-tested, of which seed had become available. The varieties and strains were planted in four replicated blocks with plots of single rows 30 ft. long spaced 1 ft. apart. This trial was planted in soil that had carried an infected crop of Reeves during the previous season, but to ensure adequate infection diseased plants were spread evenly in the rows prior to sowing. Figures for the varieties appear in Table 4 and for the Giant and Cristaudo strains in Table 5.

Table 4.

STEM ROT VARIETAL RESISTANCE TRIAL, BRISBANE, 1954–55.

Variety.	Percentage of Plants Infected.
Blackeye 5	1·8
Malabar	16·5
Early Giant	30·4
Giant	30·8
Soutter	40·3
C.P.I. 9432	66·8
Arlington	67·6
Buff	70·5
Iron	79·4
Cristaudo (Commercial) ..	91·5
Black	96·5
Reeves	99·9
Poona	100
Early Red	100

Necessary differences for significance, 5% — 13·0; 1% — 17·4.

Table 5.

REACTION OF VARIOUS STRAINS OF CRISTAUDO AND GIANT TO STEM ROT, BRISBANE, 1954–55.

Strain.	Percentage Infection.
Giant (Commercial) ..	30·8
Giant (1)	22·3
Giant (2)	28·1
Giant (3)	32·9
Cristaudo (Commercial) ..	91·5
Cristaudo (1)	51·1
Cristaudo (2)	56·9
Cristaudo (3)	83·7

Necessary differences for significance, 5% — 13·0; 1% — 17·4.

Blackeye 5 and Malabar showed very good resistance, while Giant and Early Giant were moderately resistant. Little variation was encountered between strains of Giant, but as expected there was evidence of differing resistance between strains of Cristaudo.

(4) 1955-56 Season.

In the 1955-56 season, trials were conducted over a range of conditions in south-eastern Queensland. As a result of previous work the following 10 varieties were selected for testing:—Poona, Reeves, Soutter, Giant, Cristaudo (1), Cristaudo (2), Early Giant, Havana, Blackeye 5, and Malabar.

Trials 1, 3 and 4 were planted in six replicated blocks, trial 2 in five. Plots were of single rows 30 ft. long. The trials were completely surrounded by rows of the susceptible check, Poona. Seasonal conditions in all cases were abnormally wet. A brief outline of each of the trials follows and the results appear in Tables 6 and 7.

Fig. 3.

Stem Rot Resistance Field Trial, Kumbia, 1955–56. In the foreground is the variety Cristaudo and in the rear Malabar.

Trial 1 was located at Kumbia, in the South Burnett, on land which had carried two successive crops of cowpeas affected with stem rot. (In 1954-55 the variety Poona was completely destroyed.) From the time of planting in December until the end of April, over 33 inches of rain fell. Besides losses from *Phytophthora vignae* there were losses from stem rot causes by *Rhizoctonia* sp. and *Sclerotium rolfsii;* Fusarium wilt (*F. oxysporium* f. *tracheiphilum*) was also present. The incidence of these three diseases was slight and their damage was completely overshadowed by losses due to *P. vignae.* This trial represented the conditions that would occur in the field on land having a history of heavy stem rot infection.

The resistance of Blackeye 5, Havana, Malabar (Fig. 3) and Giant was demonstrated, while Cristaudo proved very susceptible (Fig. 3) and Poona was a complete loss (Fig. 4).

Fig. 4.

Stem Rot Resistance Field Trial, Kumbia, 1955–56. Varieties, from left to right, are Giant, Poona, Blackeye 5 and Havana.

Trial 2 was conducted at Moffatdale, also in the South Burnett district. Some details of this trial have already been outlined in an earlier paper (Purss 1957) because of the results obtained over the range of moisture conditions prevailing between blocks. It was located on soil into which a crop of Poona lightly affected with stem rot was ploughed just prior to planting. As the area was subject to flooding it was impossible to count emergence or assess disease incidence at regular intervals. Consequently, the losses recorded include minor losses such as plants washed out by flowing water. The ability of Blackeye 5 and Havana to withstand severe conditions induced by the flooding is demonstrated.

Table 6.

INCIDENCE OF STEM ROT AT THREE LOCALITIES IN SOUTH-EASTERN QUEENSLAND, 1955–56. (EXPRESSED AS PERCENTAGE OF PLANTS INFECTED).

Variety.	Trial 1, Kumbia.	*Trial 2, Moffatdale.	Trial 3, Redlands.	Mean.
Blackeye 5	0·9	20·0	1·5	7·5
Havana	2·3	19·0	0·5	7·3
Malabar	13·4	67·9	1·5	27·6
Giant	8·3	62·2	5·0	25·2
Early Giant ..	34·6	64·6	6·0	35·1
Soutter	38·9	66·6	26·0	43·8
Cristaudo (1) ..	81·9	62·5	7·0	50·5
Cristaudo (2) ..	75·8	67·9	7·0	50·2
Reeves	84·6	91·3	83·0	86·3
Poona	99·5	96·9	91·0	95·8

* Based on losses from all causes (see text).

Trial 3 was located in the Redlands district, near Brisbane, on soil which had carried two successive crops of cowpea in which stem rot had occurred only in patches. Dry conditions were experienced during the first month but thereafter the trial was subjected to rainfall conditions similar to those encountered in Trials 1 and 2. The results are typical of those normally associated with a low inoculum level in the soil and show the resistance of Cristaudo under such conditions.

Trial 4 was conducted at Fraserview in the Fassifern Valley on the site used for the trials in the 1952-53 and 1953-54 seasons. The area was planted to a susceptible variety in the 1954-55 season and complete loss from the disease was reported. Very wet conditions were experienced throughout the trial, making emergence counts impossible, and results are therefore expressed as the total final stand (Table 7). Striking differences in susceptibility between

Table 7.

STEM ROT RESISTANCE TRIAL NO. 4, FRASERVIEW, 1955–56.

Variety.	Total Final Stand.
Havana	371
Blackeye 5	337
Malabar	46
Soutter	49
Giant	23
Cristaudo (1)	8
Cristaudo (2)	4
Early Giant	2
Reeves	5
Poona	0

varieties under these conditions of heavy inoculum level and heavy rainfall bordering on flood conditions are revealed. The resistance of Blackeye 5 and Havana is demonstrated.

(5) 1956-57 Season.

In the 1956-57 season a further trial using four replications was conducted at Kumbia on the land previously used for such trials. Conditions during this season were exceptionally dry. The results given in Table 8 reveal the field resistance of Santiago.

Table 8.

STEM ROT RESISTANCE TRIAL, KUMBIA, 1956–57.

Variety.	Percentage Infection.
Poona	97
Blackeye 5 ..	0
Havana	0
Malabar ..	3
Santiago ..	0·2
C.P.I. 9322 ..	58
Giant	3·4

V. BREEDING FOR DISEASE RESISTANCE.

Early in the testing programme it became apparent that the popular Poona variety was extremely susceptible and that new varieties would need to be introduced or synthesised by plant breeders. In an attempt to obtain simple information on the inheritance of disease resistance, Poona was crossed with the resistant Blackeye 5. The F_1 generation was tested immediately and backcrossed to Poona. This backcrossing programme has continued, the ultimate objective being a resistant backcross Poona. All testing done has been in pots, the plants being individually inoculated with *P. vignae*. The results of these inoculations are summarised in Table 9.

Table 9.

RESULTS OF INOCULATING VARIOUS GENERATIONS OF A POONA AND BLACKEYE 5 CROSS WITH *P. vignae*.

Generation.	No. of Plants.	No. Healthy.	No. Diseased.
Blackeye 5—Parent	10	10	0
Poona—Parent	10	0	10
Poona x Blackeye 5—F_1 ..	10	10	0
—F_2 ..	109	83	26
1st B.C.	83	48	35
2nd B.C.	70	41	29

Fig. 5.

The Parents and Progeny of the Poona x Blackeye 5 Cross. From left to right—Poona, two F_1 plants, and Blackeye 5.

Fig. 6.

General View of First Backcross Selfed Lines of the Poona x Blackeye 5 Cross Growing on Infested Soil in the Field.

The two parents and two of the F_1 plants are shown in Fig. 5, and Fig. 6 is a general view of some of the 1st backcross selfed lines growing on infested soil.

The results indicate that the resistance to stem rot possessed by Blackeye 5 is dominant over susceptibility.

VI. DISCUSSION.

The most striking feature of these results is the difference in reaction in some of the varieties under glasshouse, plot and field conditions. The varieties can be roughly grouped into three classes.

In the first are included those that are very susceptible under all conditions of testing. Into this group such varieties as Poona, Reeves, Black and Arlington can be placed.

In the second class are varieties which are very susceptible in pots but which show variable reaction under other conditions of testing. Into this group are placed such varieties as Malabar and Giant, which possess very good "field resistance", and Soutter and Early Giant, which show this to a lesser degree. The variety Cristaudo also comes into this group; its behaviour will be referred to later. It is within this class that we find the greatest effect of environmental conditions, such as previous history of the land in respect of number of infected cowpea crops carried, and seasonal conditions such as high rainfall and flooding.

The third class contains those varieties which maintain resistance under all manner of conditions. Included here are Blackeye 5, Havana and Santiago. Chinese Red, which withstood the glasshouse testing, probably could be included.

That such a grouping is possible would indicate that there are at least two distinct types of resistance. On the one hand there is the type possessed by the group containing Blackeye 5, which appears to be almost an immunity. On the other hand is the resistance possessed by such varieties as Malabar and Giant, a resistance best described as a field resistance which breaks down when conditions are very favourable to the pathogen and when the inoculum potential is high.

Reference has already been made to the build-up of the disease which occurs when susceptible varieties are grown season after season on the same ground (Purss 1957). The results of the trials during 1956-57 are very striking in this regard. Trial 1 at Kumbia (Table 6) was carried out on soil which had carried a very badly affected crop during the previous season. The trial at Redlands had carried infected crops but this infection had been somewhat restricted. The varieties Poona and Reeves were equally susceptible under both conditions of testing, while Havana and Blackeye 5 were equally resistant. Differences, however, appeared in the second group of varieties—Malabar, Giant, Cristaudo and to some extent Soutter. This was even more pronounced

in the trial at Moffatdale, where Malabar became badly affected owing to the flooded conditions.

The behaviour of the variety Cristaudo deserves some special comment because of the resistance this variety possessed in earlier trials (Purss 1953). The explanation of the failing resistance appears to lie in the build-up of inoculum levels. The difference in results at Redlands and the South Burnett (Table 6) illustrates this. The variety still maintains good field resistance where the inoculum level is low, a condition which was probably universal in 1953, but this resistance breaks down when the inoculum level is increased, as in Trial 1, 1956-57. The resistance also breaks down when seasonal conditions are extremely favourable to the disease, as at Moffatdale in 1956-57. There is also evidence of extreme variability between strains of Cristaudo in regards to their reaction to this disease. Both Cristaudo and Giant were developed by farmers for use in northern canefields and have not been intensively selected. The variety Cristaudo is not regarded favourably by agronomists and for this reason and the low order of resistance available it was not considered worthwhile to build up seed stocks of the more resistant lines.

VII. CONCLUSION.

The information presented indicates that the threatened elimination of the cowpea as an agricultural crop in Queensland on account of stem rot disease may be avoided by the use of resistant varieties. Of those already tested, Havana and Blackeye 5 withstand the disease under all conditions while Malabar and Giant possess resistance ample enough to withstand most conditions likely to be encountered in the field. These varieties may not have all the characteristics which made the displaced Poona variety so popular, but at least they closely approach the desired type.

It is apparent that should none of the resistant varieties already obtained be wholly suitable, the production of a suitable disease-resistant variety by plant breeders should present no insuperable problems.

Fortunately, all other tropical and subtropical legumes so far tested appear to be resistant to the disease.

VIII. ACKNOWLEDGEMENTS.

The assistance given by the C.S.I.R.O. Plant Introduction Section in providing seed of cowpea introductions is gratefully acknowledged. Many officers of the Agriculture and Horticulture Branches of the Department of Agriculture and Stock assisted in the conduct of the field trials. This assistance was invaluable.

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THE OCCURRENCE OF A HIGHLY ALKALINE SOLONETZ SOIL IN SOUTHERN QUEENSLAND

By R. F. ISBELL, M.Sc., Chemical Laboratory, Division of Plant Industry.

SUMMARY.

A highly alkaline solonetz soil occurring around Yelarbon is described.

It is suggested that underground water of a high sodium bicarbonate content associated with a fluctuating water-table is responsible for the highly alkaline nature of the soil.

I. INTRODUCTION.

Recent soil survey work in the southern border areas of Queensland (Isbell 1957) has disclosed the presence of an area of a highly alkaline soil which from its morphological and chemical features is thought to be a typical solonetz. The soil occurs surrounding the township of Yelarbon (200 miles south-west of Brisbane) and occupies an area of 10,000-12,000 acres. It is associated marginally with a smaller area of typical solodized-solonetz soils. Its characteristic properties have resulted in the development of an unusual plant community, the stunted and impoverished nature of which has caused the area to be popularly referred to as the Yelarbon "desert".

Skerman (1948) drew attention to the frequent association of sandalwood (*Eremophila mitchellii*) and bull oak (*Casuarina leuhmannii*) with soils characterised by high amounts of exchangeable sodium and/or magnesium. However, although he referred to such soils as solonetz, more recent studies have indicated that the majority, if not all, are better regarded as typical solodized-solonetz soils.

II. THE ENVIRONMENT OF THE AREA.

(1) Climate.

The area has an average annual rainfall of 25 inches, two-thirds of which falls during the summer months of October to March inclusive. Summer temperatures are hot, with the mean maximum for the months of December, January and February being in the vicinity of 92 deg. F. The mean minimum temperature for July, the coldest month, is 41 deg. F. Frosts are common and frequently severe during the winter months.

(2) Geology.

The area is topographically almost level and no surface rock outcrops, except a low ridge of conglomerate and coarse grits situated marginally to the solonetz soils three miles east-north-east of Yelarbon, are present. Although poorly exposed, the upper section of this deposit is heavily impregnated with limonitic material, while at shallow depths this is replaced by an almost white conglomerate. This occurrence appears to underlie the

Yelarbon "desert", as shallow wells in the township penetrate water-bearing gravels, while to the north of Yelarbon near the desert margin an excavated earth tank has exposed weakly cemented white sandstones and grits which may occasionally display a very weak orange mottling. Soil-boring investigations have also revealed the presence of uncemented sands at relatively shallow depths south-east of Yelarbon.

Sediments similar to this are not known from elsewhere in this southern border region but it is likely that they represent a late Tertiary or Pleistocene deposit. In many features they resemble the Pliocene Glendower Formation (Whitehouse 1940).

(3) Vegetation.

On the solonetz soils and also on some areas of the marginal solodized-solonetz soils an interesting *Melaleuca adnata* (tea-tree)-*Triodia irritans* (spinifex) community is developed. The spinifex does not form a continuous ground cover but occurs as fairly large separate clumps. Much of the area presents a scalded claypan-like appearance due to erosion (apparently mainly by wind) of the surface soil horizons.

The tea-tree is always stunted in habit and may occur singly or in small thickets. Also fairly common are low shrubby stands of sandalwood (*Eremophila mitchellii*), many of which are dead. This general stunted aspect of the

Fig. 1.

View of the Yelarbon "Desert", Showing Vegetation of Spinifex, Bull Oak and Tea-tree (background) Developed on the Highly Alkaline Solonetz Soil.

community is quite characteristic, but isolated tree species do occur. These are mainly bull oak (*Casuarina leuhmannii*), poplar box (*Eucalyptus populnea*) and mallee box (*E. pilligaensis*). Normally there is little ground cover apart from the spinifex, although in areas where the topsoil has not been removed there is a sparse growth of *Chloris divaricata* and *C. truncata*. Where overgrazing has been severe, there may be a dense growth of *Bassia tricuspis* and *Salsoli kali*.

The boundary of this typical "desert" community is not sharp except in the south. Where it merges into the surrounding brigalow (*Acacia harpophylla*) and belah (*Casuarina lepidophloia*) forests there is a narrow marginal zone in which there is very little, if any, spinifex and much less tea-tree but an influx of stunted brigalow and belah.

III. DESCRIPTION OF THE SOILS.

(1) The Solonetz Soil.

As Kelley (1951) has pointed out in his review of alkali soils, the Russian term solonetz has not always been used in exactly the same sense. In his early work on alkali soils Gedroiz (1912) used "solonetz" in the sense of a soil containing excessive exchangeable sodium. However, later both he and other Russian workers referred to solonetz as a leached alkali soil, the sub-horizons of which contained more or less exchangeable sodium and the profile of which showed a certain peculiar morphology while there was an absence, or only low concentration, of salts except at considerable depth.

In more recent years many of the soils which would have earlier been designated solonetz have been called solodized-solonetz, but again there has not always been uniformity of usage, some authors placing the emphasis on pure morphology and others on the chemistry of the soils. Thus in Australia Stephens (1953) placed emphasis almost entirely on morphology, while Hallsworth, Costin and Gibbons (1953) in addition stressed the chemical features. In this present study the diagnostic features of a solonetz soil are taken to be those indicated by Hallsworth *et al.* Thus the solonetz profiles are alkaline throughout, strongly so in the subsoils which contain much exchangeable sodium. The B horizon usually displays well developed columnar structure and may or may not be capped by a bleached A_2 horizon.

In the vicinity of Yelarbon the solonetz soils normally have a fairly thin A_1 horizon (up to 4 inches) but this thickness may be increased locally by accessions of wind-eroded material, especially where spinifex clumps exert a binding effect. In other areas the A_1 horizon may be entirely removed.

Usually it is an almost structureless, rather soft, light greyish-brown loam or clay loam which may occasionally give a faint acid effervescence. An A_2 horizon of similar texture may be present, but if so is only slightly bleached.

The B horizons are fairly sharply defined from the A, but although they are clays in texture their consistence is not as hard and tough as in the solodized-solonetz soils. The brownish B horizons have an extremely low permeability to water, in spite of the fact that they appear slightly vesicular. Even after prolonged steady rainfall there is very little penetration of water below the A horizon. Where the A horizon has been stripped by erosion the exposed B horizon will not support any plant growth.

The B_{21} horizon often displays a coarse prismatic or columnar structure, the columns ranging from 6 to 18 inches in diameter and possessing a gently domed upper surface. The B_{21} merges gradually into the B_{22} horizon, which is massive and rather more friable and contains numerous black fleckings, some of which are possibly organic stainings. The deeper horizons are a brown to greyish-brown friable clay which becomes increasingly sandy with depth. Free carbonate is present in the B horizons and increases with depth, becoming prominent in the form of fairly large nodules. It appears from tests that some of this material is sodium carbonate.

Fig. 2.

The Top of the B Horizon of the Solonetz Soil Exposed by Erosion and Showing the Well Developed Irregular Columnar Structure. The columns are only slightly domed.

The following profiles illustrate the features of the solonetz soils:—

(i.) Profile 3 miles south of Yelarbon along the Keetah road.

A_1	0- 3 in.	Light greyish-brown clay loam, fairly soft and massive, slightly bleached at the base (incipient A_2), fairly sharply defined from
B_{21}	3- 10 in.	Brown medium clay, moderately coarse prismatic structure, hard, merges into
B_{22}	10- 24 in.	Light-brown medium clay, angular blocky to massive, fairly friable, trace of carbonate, merges into
BC	24- 36 in.	Yellowish-brown light clay, friable, slight carbonate.

(ii.) Profile approximately 3 miles south-east of Yelarbon.

A_1	0- 4 in.	Light brownish-grey clay loam, slightly platy on surface then massive and rather vesicular, slightly hard, fairly well defined from
A_2	4- 10 in.	Light-brown clay loam, massive but finely vesicular and fairly hard, not a very sharp break to
B_{21}	10- 18 in.	Brown clay with slight grey mottling and numerous black fleckings. Fairly coarse columnar to prismatic structure with diameter of columns 6-18 in. Still slightly vesicular, hard with a trace of carbonate.
B_{22}	18- 36 in.	Light-brown clay, massive but more friable, some carbonate nodules.
BC	36- 60 in.	Light greyish-brown clay, slightly sandy at depth, fairly friable, with some carbonate nodules.
	60- 72 in.	Pale greyish-brown sandy clay, massive and rather vesicular, with black stainings and some large carbonate nodules but little or no fine earth effervescence.
	72-108 in.	Pale greyish-brown sandy clay loam to loam with some soft carbonate patches.

108-132 in. Light-grey to very pale brownish-grey loamy sand, rather cemented. Mass appears very vesicular but is difficult to wet.

132-162 in. Light-grey to very pale brownish-grey sand, loose and uncemented.

162-192 in. Light-brown slightly coarser sand, loose and soft.

Below 18 in. all horizon boundaries are diffuse and any changes are very gradual.

Analytical Data.

Data for profile (ii.) are shown in Table 1. A particle size analysis shows a moderately high content of fine sand in the A_1 horizon; this is probably partly due to accessions of wind-blown material. A further feature of interest is the rather high silt content throughout the three horizons analysed and the moderately low clay content of the B_{22} horizon.

Table 1.

ANALYTICAL DATA FOR PROFILE (ii).

Lab. No.	1500		1501.		1502.		1503.		1504.	1505.	1506.
Depth (in.)	0–4		4–10		10–18		18–36		36–48	48–60	60–70
Horizon	A_1		A_2		B_{21}		B_{22}		BC	C	C
Texture	CL		CL		C		C		C	C	C(sl.S)
pH	8·1		9·3		10·2		10·2		10·1	10·1	10·1
Free Carbonates (as% CO_2)	..		..		0·7		0·4		..	..	..
Mechanical Analysis(%)	..		..		..		..		..	..	..
Coarse sand ..	1·7		6·7		..		13·0		..	..	..
Fine sand	34·6		15·4		..		14·3		..	..	..
Silt	37·3		45·7		..		32·1		..	..	..
Clay	17·5		29·7		..		36·8		..	..	..
Moisture	1·6		1·9		..		4·5		..	..	..
Organic Carbon (%) ..	0·85		0·62		..		..		..	..	..
Nitrogen (%)	0·07		0·03		..		..		..	..	..
Available P_2O_5 (p.p.m.)	32		16		84		264		170	128	114
Chloride as NaCl (%)	0·020		0·043		0·043		0·071		0·070	0·070	0·066
Specific Conductivity (mhos x 10^{-3}) ..	0·09		0·18		0·52		0·80		0·59	0·57	0·55
Exchangeable Cations*	A	B	A	B	A	B	A	B	..	..	..
Calcium	2·7	26	1·5	11	19·0	42	13·8	35	..	..	..
Magnesium	6·0	58	7·5	54	10·2	23	7·3	18	..	..	..
Potassium	0·2	2	0·4	2	0·4	1	0·4	1	..	..	..
Sodium	1·4	14	4·6	33	15·3	34	18·3	46	..	..	..
Total Metal Ions ..	10·3	100	14·0	100	44·9	100	39·8	100	..	..	..

* A = mg. = equiv./100 g. of soil. B = percentage composition of the exchangeable metal ions.

The A_1 horizon is moderately alkaline, and the remainder of the profile very strongly alkaline (pH 10.0 in the B and lower horizons). Magnesium is the dominant exchangeable metal cation in the A_1 horizon; calcium is subdominant and sodium is also significant. In the A_2, sodium shows a fairly sharp rise and calcium and magnesium remain more or less constant. In the B_2 horizons both calcium and sodium show a very marked increase, with the exchangeable sodium rising to 18 m-equiv. per cent. (46 per cent. of the total exchangeable metal cations) in the B_{22} horizon. Magnesium does not show an appreciable increase in the B horizons and is subordinate to both sodium and calcium. Exchangeable potassium is present in normal amounts throughout. Chloride and total soluble salt contents increase to a maximum in the B_{22} horizon but values are not unduly high (0.07 per cent. NaCl). "Available" phosphate (Kerr and von Stieglitz 1938) is low in the A horizons but shows a very marked increase in the B_2 and lower horizons.

(2) The Solodized-Solonetz Soils.

Marginally in most areas the solonetz soils grade into less alkaline, typical solodized-solonetz types which support a more normal vegetation. These soils have a thin loam or clay loam A_1 horizon (seldom exceeding 4 inches) and usually a bleached A_2 which may be strongly developed. The B horizon is a very tough dense clay or sandy clay which frequently displays columnar or prismatic structure. The following profile from 0.75 miles north of Yelarbon is characteristic:—

A_1	0- 2 in.	Grey loam, compact and slightly hard, merges into
A_2	2- 4 in.	Light-grey sandy clay loam, strongly bleached, massive and fairly hard, sharply defined from
B_{21}	4- 8 in.	Grey-brown heavy clay to sandy clay with light grey mottling. Very hard and tough with some degree of columnar to prismatic structure. Merges into
B_{22}	8- 24 in.	Grey-brown sandy clay, coarse blocky to massive, more friable, merges into
BC	24- 36 in.	Grey-brown clay, slightly gritty with some orange mottling. Friable with free carbonate increasing with depth.

Analytical Data.

The A horizons of these solodized-solonetz soils are slightly acid to neutral and the B horizons are only moderately alkaline (reaching a maximum

of pH 8.2 in the B_{22} horizons). The exchangeable metal cations are dominated by magnesium; although sodium is still high it rarely reaches the levels obtained in the solonetz profiles. Chloride and total soluble salt contents are lower in the A horizons than in the solonetz soils, but chloride reaches higher levels in the B_{22} and deeper horizons. "Available" phosphate is very variable but may be very low throughout the profile.

IV. DISCUSSION.

As mentioned earlier, the Yelarbon area is underlain at shallow depths by a series of water-bearing gravel and sand beds. Well records indicate a very marked fluctuation in this perched water-table. After periods of heavy rains it may rise almost to the surface and it is apparently never much deeper than 40 ft. below the surface. Analyses of this water show a high content of sodium bicarbonate (some 12 m-equiv./litre) so that it would appear that this fluctuating water-table affords a most likely explanation for the highly alkaline nature of the solonetz soils. However, there is no evidence to suggest an ultimate origin for the sodium salts; possibly the sediments themselves were inherently salty. Water from the nearby Macintyre Brook is not unduly salty even in dry periods, yet there is some evidence to indicate a relation between the water level in this stream and the height of the perched water-table in the vicinity of Yelarbon.

Possibly the marginal solodized-solonetz soils could represent a stage in the desalinisation of the solonetz soils; some exchangeable sodium has been removed from the exchange complex and soluble salts have been washed further down the profile. On the other hand, field evidence indicates that the solonetz soils are not being leached to any extent under present conditions, so it may be that these marginal soils did not originally contain excessive amounts of sodium salts.

Finally, it may be mentioned that the chemical and physical properties of the solonetz soils prohibit most plant growth. Any possible reclamation is likely to be difficult. Limited experimentation has shown that deep ripping to ensure better water penetration and consequent leaching has effected some improvement, but the presence of the salty water-table at often shallow depths still remains the fundamental cause of the alkalinity problems.

V. ACKNOWLEDGEMENTS.

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SOME ASPECTS OF OESTRUM IN CATTLE, WITH REFERENCE TO FERTILITY ON ARTIFICIAL INSEMINATION. 1. THE PATTERN OF OESTROUS CYCLES

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SUMMARY.

Aspects of the incidence of oestrum, together with fertility data, have been investigated in Jersey cows in south-eastern Queensland.

For 383 cows, the mean interval between parturition and first oestrum was 40·45±22·70 days. The modal interval occurred at 26–30 days, and 79 per cent. of the cows exhibited first heat 11–55 days after calving. Fertility data indicated that fertility at first heat is a function of the past-partum interval rather than of any characteristic of first heat per se.

Of 441 non-service oestrous cycles, 18·4 per cent. were less than 18 days in duration. Approximately 94 per cent. of the short cycles occurred between first and second heats. Short cycles were also recorded in the case of 10·9 per cent. of 567 service-return cycles, but were not so closely associated with first heat. Fertility rates for cows artificially inseminated after short cycles were similar for first and repeat inseminations and were of the order of 57 per cent.

Non-service cycles exceeded 25 days in 11·4 per cent. of cases, whereas 33·3 per cent. of service-return cycles were of long duration. First insemination fertility (79 per cent.) after such long cycles was markedly higher than that of repeat inseminations performed after long service-return cycles (55 per cent.).

Attention is drawn to the importance of the high incidence of short oestrous cycles in the overall pattern of ovarian dysfunction in the area concerned.

I. INTRODUCTION.

While reproductive processes in the bovine have been the subject of extensive investigation in other parts of the world, little factual information is available in respect of Australian cattle. Current husbandry practices in this country in relation to breeding are determined by recommendations derived from elsewhere. In particular, routine artificial insemination in Australia closely follows practices developed in other countries. While it is possible that such practices are optimal for fertility in Australian cattle, it is considered that the factors involved should be under constant review.

In 1955 the Queensland Department of Agriculture and Stock inaugurated a Bull Proving Project to locate dairy sires of outstanding genetic merit in Queensland studs. The programme is very similar to that being currently pursued in the United Kingdom. Initially, the Jersey breed is under consideration. Each year a team of four young bulls is placed under test, and semen from each bull is used for the artificial insemination of at least 250 cows. The cows belong to about 50 commercial dairymen in the Nambour region, approximately 70 miles north of Brisbane.

During the 1955 breeding season it was found that approximately 17 per cent. of 339 cows which failed to conceive to first insemination returned on heat within 2-17 days. This result is at considerable variance with reports from certain other sources (Asdell 1946, Erb 1955, Joubert 1955). Therefore, it was considered of value to investigate the pattern of oestrous cycles more fully in the 1956 breeding season, especially in relation to possible influences on fertility.

II. MATERIAL AND METHODS.

In the 82-days' period from Oct. 1 to Dec. 21, 1956, 1,267 cows were presented for artificial insemination. In addition to these first inseminations, 398 repeat inseminations were performed. As each insemination was carried out, available data concerning the cow's previous reproductive performance were recorded by the inseminator. Information relating to service-return oestrous cycles was available from the artificial insemination records.

Inseminations were performed by the rectal fixation technique, approximately 1 ml. of chilled extended semen being deposited in the uterine cornua and in the cervical canal.

Fertility or breeding efficiency has been calculated on the basis of 60–90 day non-returns. Overall first insemination fertility in 1956 was of the order of 64 per cent.

III. RESULTS.

(1) Post-partum Interval to First Heat.

Data were available for the intervals between calving and first heat in respect of 383 cows. The distribution of the intervals is presented in Fig. 1. It was found that the mean period between parturition and first oestrum was $40{\cdot}45 \pm 22{\cdot}70$ days. The modal interval occurred at 26–30 days, and 79 per cent. of the cows exhibited first heat 11–55 days after calving.

(2) Non-Service Oestrous Cycles.

Complete information concerning 441 dioestrous intervals, in the absence of service, was available for 281 cows. The data are presented in Table 1 and Fig. 2. While it is to be expected that a large proportion of the intervals should fall within the range 18–25 days, it is considered noteworthy that 18·4 per cent. of the intervals were shorter than 18 days. Further examination of the data indicates that a high proportion (93·8 per cent.) of the short cycles occurred between first and second heats. No relationship between the incidence of short cycles and other aspects of oestrum, such as the post-partum interval to oestrum, preceding cycle length and succeeding cycle length, could be established.

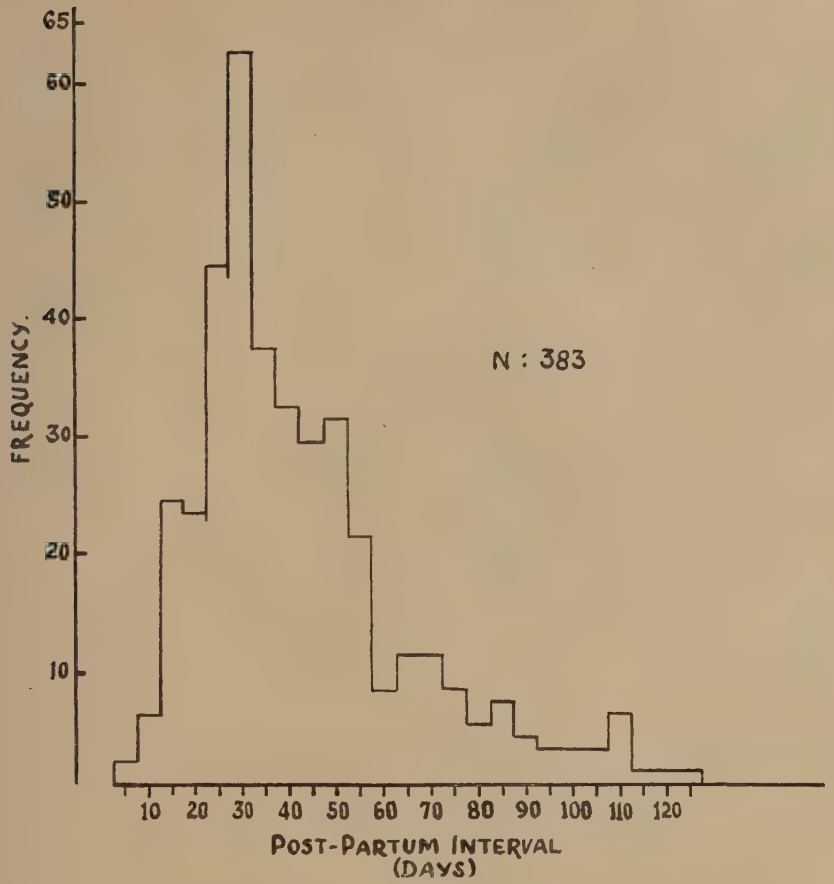

Fig. 1.

Distribution of the Post-partum Interval to First Heat.

Table 1.

DISTRIBUTION OF NON-SERVICE OESTROUS CYCLES.

Interval Between Respective Heats. (Days.)	Heats.								
	I.–II.		II.–III.		III.–IV.		IV.–V.	Over-all.	
	No.	%.	No.	.%	No.	%.	No.	No.	%.
0—17	76	27·1	3	2·6	2	4·9	..	81	18·4
18—25	167	59·4	103	88·8	36	87·8	3	309	70·1
26—65	38	13·5	10	8·6	3	7·3	..	51	11·5
Total Cycles	281	..	116	..	41	..	3	441	..

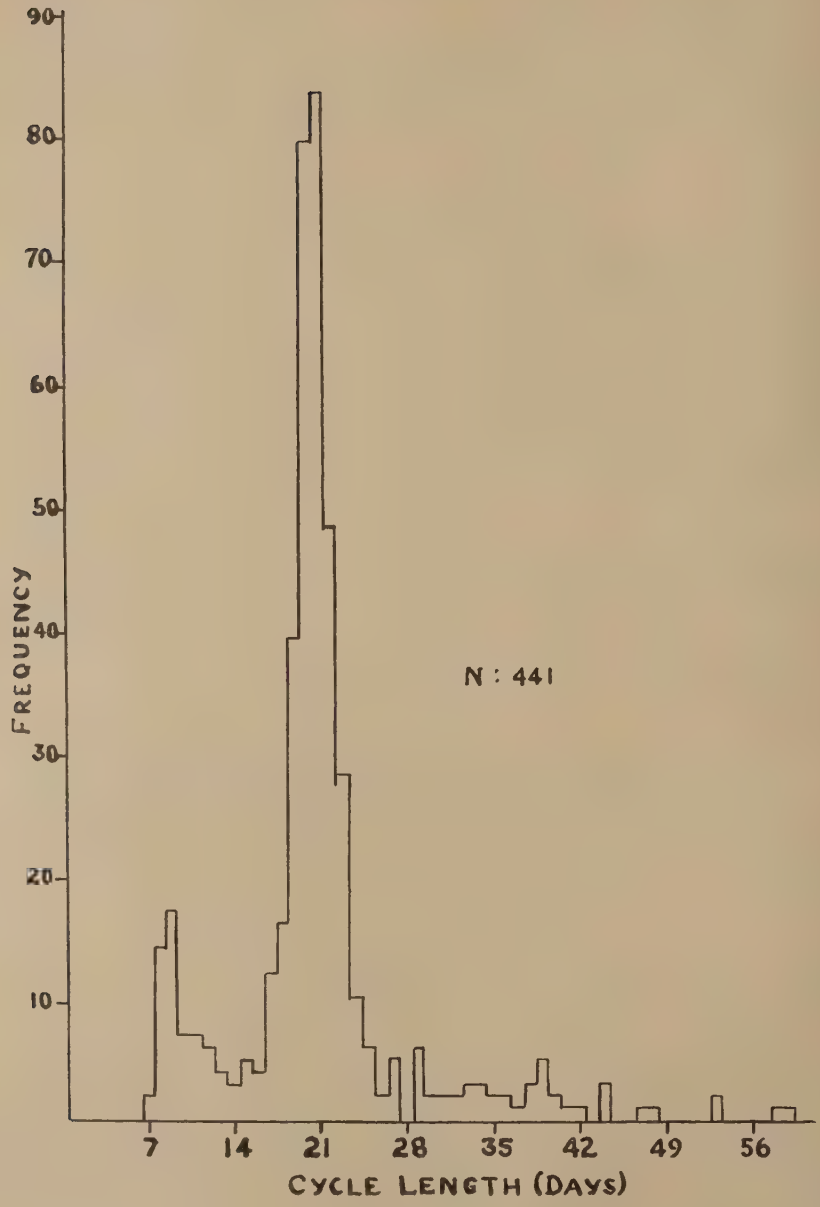

Fig. 2.

Distribution of Non-service Oestrous Cycles.

(3) Fertility at First Heat.

To effect a more complete appraisal of fertility at first heat, the effect on fertility of the post-partum interval before service, *per se*, was examined. It is apparent (Table 2) that fertility levels improved as the interval between calving and insemination increased. It was noted above that a large proportion of cows exhibited first heat 11–55 days after calving. The fertility of cows inseminated when first heat occurred in the "normal" range (52 per cent.) was markedly lower (Table 3) than that of cows inseminated when first heat occurred after a longer interval (62 per cent.). The indications are, therefore, that fertility at first heat is related more to the length of the post-partum interval than to any characteristic of first heat, *per se*.

Table 2.

INFLUENCE ON FERTILITY OF THE POST-PARTUM INTERVAL TO SERVICE.

Interval Between Calving and 1st Insemination. (Days.)	No. of Cows Inseminated.	Fertility. (%)
1—40	114	57
41—55	180	59
56—100	547	66
101—150	124	71
Total ..	965	64

Table 3.

FERTILITY AT FIRST HEAT.

Post-partum Interval to 1st Heat. (Days.)	No. of Cows Inseminated.	Fertility. (%)
11—55	54	52
56—130	53	62
Total ..	107	57

(4) Influence of Dioestrous Interval on Fertility.

A wide range in the length of the dioestrous interval has been noted above. Since most of the short cycles occur before second heat, when service is often performed, the influence that such variations in intervals might exert on fertility was examined. It was found (Table 4) that fertility is depressed after short dioestrous intervals, but may be quite high after long intervals.

(5) Service-Return Oestrous Cycles.

Data were available for 567 oestrous cycles following unsuccessful insemination. An analysis of the distribution of those cycles, as compared with the distribution of non-service cycles (Table 5), indicates a tendency for

Table 4.

INFLUENCE OF THE DIOESTROUS INTERVAL ON FERTILITY.

Length of Previous Dioestrous Interval. (Days.)	Fertility Results.					Fertility. (%)
	Heat II.	Heat III.	Heat IV.	Heat V.	Total.	
0—17	29 (16)	3 (2)	2 (1)	– (–)	34 (19)	56
18—25	98 (61)	64 (38)	33 (21)	3 (3)	198 (123)	62
26—65	28 (21)	11 (9)	3 (3)	– (–)	42 (33)	79
Total	155 (98)	78 (49)	38 (25)	3 (3)	274 (175)	..
Fertility (%)	63	63	66	..	64	..

*Numbers in brackets refer to 60-90-day non-returns.

Table 5.

PATTERN OF OESTROUS CYCLES.

Length of Cycle. (Days.)	Non-Service Cycles.		Service-Return Cycles.	
	No.	%.	No.	%.
0—17	81	18·4	62	10·9
18—25	309	70·1	305	53·8
26—	51	11·5	200	35·3
No. of Cycles ..	441	..	567	..

Table 6.

DISTRIBUTION OF SERVICE-RETURN OESTROUS CYCLES AFTER FIRST AND REPEAT INSEMINATIONS.

Length of Service-Return Oestrous Cycle. (Days.)	1st Insemination Returns.		2nd Insemination Returns.		3rd Insemination Returns.	
	No.	%.	No.	%.	No.	%.
0—17	47	11·0	8	8·1	7	18·0
18—25	226	52·6	58	58·6	21	53·8
26—	156	36·4	33	33·3	11	28·2
No. of Cycles	429	..	99	..	39	..

service-return cycles to be longer than non-service cycles. The data have been further analysed in Table 6 to present the distribution of service-return cycles after first and repeat inseminations. It is apparent that a similar trend occurred in each instance.

(6) Service-Return Oestrous Cycles after Respective Heats.

Although more than 90 per cent. of short non-service oestrous cycles occurred between first and second heats, it was found that short service-return cycles were not so closely associated with first heat (Table 7).

Table 7.

SERVICE-RETURN OESTROUS CYCLES AFTER FIRST INSEMINATION AT RESPECTIVE HEATS.

Length of Service-Return Oestrous Cycle. (Days.)	Cows Returning after Insemination.								
	Heat I.		Heat II.		Heat III.		Heat IV.	Over-all.	
	No.	%.	No.	%.	No.	%.	No.	No.	%.
0—17	9	20·9	6	10·5	..	..	..	15	10·6
18—25	19	44·2	38	66·7	19	65·5	9	85	60·3
26—	15	34·9	13	22·8	10	34·5	3	41	29·1
No. of Cycles ..	43	..	57	..	29	..	12	141	..

(7) Influence of Length of Preceding Service-Return Cycle on Fertility of Repeat Inseminations.

Although an overall depression in fertility (57 per cent.) occurred in repeat inseminations performed after short service-return cycles (Table 8), quite high fertility was obtained in second inseminations performed after such cycles. It is of interest to note that the fertility of repeat inseminations performed after long cycles (55 per cent.) is markedly lower than that of first inseminations carried out after long cycles (79 per cent.) (see Table 4).

Table 8.

INFLUENCE OF SERVICE-RETURN CYCLE ON FERTILITY OF REPEAT INSEMINATIONS.

Length of Preceding Service-Return Oestrous Cycle. (Days.)	2nd Insemination.	3rd Insemination.	4th Insemination.	Total No.	Fertility. (%)
0—17	36 (25)	8 (1)	3 (1)	47 (27)	57
18—25	202 (139)	49 (21)	11 (10)	262 (170)	65
26—	73 (41)	11 (5)	– (–)	84 (46)	55
Total ..	311 (205)	68 (27)	14 (11)	393 (243)	..
Fertility (%) ..	66	40	..	62	..

IV. DISCUSSION.

Dairy cows in the Nambour region are subject to enzootic anoestrum (McTackett 1956a). However, because of the restricted period during which artificial inseminations are performed in the present work, a large number of cows affected with anoestrum were not offered for service. Only 3·1 per cent. of the 383 cows considered here exhibited intervals in excess of 100 days between calving and first heat. Nevertheless, the group was useful in that it has been possible to determine what may be the "normal" interval to post-partum heat in the area.

It has been adequately demonstrated by other workers that the fertility of cows is low immediately after calving, and for this reason it is recommended that cows should not be serviced until at least 60 days after calving and then at second or later heat (Patrick and Herman 1953). However, in the present work it has been noted that first heat, *per se*, is not necessarily of low fertility, and that the post-partum interval is of more significance in this regard.

In a study of the dioestrous interval, Trimberger (1956) reported that 16·34 per cent. of 584 oestrous cycles were shorter than 18 days. However, when cases of cystic ovaries were deleted, only 2·2 per cent. of 500 cycles were of short duration. It was not possible to carry out extensive and detailed ovarian examinations in the present study, but, as noted above, 18·4 per cent. of 441 cycles were of short duration. A further point of interest was the observation that most (93·8 per cent.) of the short cycles occurred between first and second heats. However, short cycles following unsuccessful insemination were not so closely associated with first heat. No tendency for short cycles to recur in individual cows was apparent. It was observed that service-return cycles tended to be longer than non-service cycles, as reported elsewhere (Chapman and Casida 1934, Olds and Seath 1951, Erb 1955, McTackett 1956b).

Considerable evidence has been presented to indicate that the fertility of cows tends to be low immediately after short dioestrous intervals (VanDemark and Moeller 1950, Moeller and VanDemark 1951, Bonfert and Fromm 1953, Bonfert 1956, Trimberger 1956). In the present study a similar trend occurred and the importance of the first dioestrous interval has been demonstrated.

It was observed that the fertility of repeat inseminations performed after long service-return cycles was markedly lower than that of first inseminations carried out after long non-service cycles. It is considered that this difference is due mainly to pathological changes in the reproductive tract associated with early post-conception failure (Tanabe and Casida 1949).

The observations reported here are considered of importance in relation to the overall pattern of infertility in the area concerned, with particular reference to ovarian dysfunction, which hitherto has been regarded as being characterised mainly by anoestrum.

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TECHNICAL NOTES

PARASITES OF SORGHUM MIDGE, *Contarinia sorghicola* (Coq.), IN QUEENSLAND

Tryon in 1894 gave an excellent description of the damage to broom sorghum by the larvae of a Cecidomyid which he considered was a species of *Diplosis*. He described the stages of the pest and remarked *inter alia* that "Already this insect, confined as far as is at present known to Southern Queensland, and believed to be a native species, is extensively parasitised by a minute hymenopterous fly belonging to the family Chalcidae, ——". The pest was obviously *Contarinia sorghicola* (Coquillet 1898).

Atherton (1941) recorded that "At least two very small wasps are parasitic on the larval or pupal stages of the sorghum midge in south-eastern Queensland". Departmental records show that the parasite species concerned were *Eupelmus australiensis* Gir. and *E. varicolor* Gir., the former being easily dominant. The type locality of both is Gordonvale, N.Q. (Girault 1915).

In January 1955 at Biloela two specimens of *Eupelmus popa* Gir. (det. Commonwealth Institute of Entomology) were bred from midge-infested *Sorghum almum* Parodi, a recent introduction into Queensland. This is the first record of *E. popa* in the State. It has been recorded from India, Java and U.S.A., where the species has been studied extensively, and it is suspected to occur in Africa (see Barnes 1956).

Eupelmus sp. nr. *longicorpus* Gir. (det. Commonwealth Institute of Entomology) was bred from Queensland blue grass (*Dichanthium sericeum* (R.Br.) A. Camus) at Biloela in January 1955. In March 1952 specimens of an Eulophid, *Tetrastichus* sp. (det. Commonwealth Institute of Entomology), were bred from the same species at Bongeen. Although *D. sericeum* is a minor but consistent host of sorghum midge, these may be doubtful records of *C. sorghicola* parasites, as the grass is a host of other midges (Tryon 1894 and Departmental Records). A species of *Tetrastichus* is a major parasite of *C. sorghicola* in Africa and was an important parasite in U.S.A. prior to 1926 (see Barnes 1956).

During the years 1950-1956, sorghum midge and parasites were bred or dissected from large numbers of field samples of sorghums, mostly *Sorghum vulgare* Pers., from the majority of Queensland sorghum-growing districts. Except for the two specimens of *E. popa* as mentioned, *E. australiensis* was the parasite invariably obtained.

C. sorghicola may place as many as 11 eggs in a floret. Seldom do more than 6 midge larvae eventuate and no more than 2 parasite larvae have been found in a floret. It is not uncommon to find 1–4 midge larvae and a parasite

larva developing concurrently to the pupal stage in the same floret. Woodruff (1929) stated that *E. popa* is a primary parasite which requires one or more midge larvae to complete its development; however, a few larvae having consumed at least one host may complete development by feeding on plant material either in the presence or in the absence of midge larvae. *E. australiensis* is also phytophagous, and there is some evidence that it will commence larval development in the absence of midge larvae; all larval stages have been found in florets in which there were no signs of midge oviposition and larval development.

E. australiensis has a wide distribution in Queensland, and is also spread with midge in sorghum seed (Passlow 1954). Nevertheless, percentage parasitism of sorghum midge is low in the early and mid-season crops and does not attain noticeable proportions until towards the end of the season: a causal factor is that the parasite emerges from its overwintering stage over a wider range of conditions than does its host from diapause. During the seven years' study period the highest percentage of parasites in any population sample was 24·2 based on total insects (parasites plus midge emerged and in diapause). The mean in late-maturing crops on the same basis was 14·1 per cent.: this level has little economic significance.

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DESTRUCTION OF SORGHUM MIDGE IN SEED GRAIN

It is well known that sorghum midge (*Contarinia sorghicola* (Coq.)), is spread as diapause larvae in consignments of seed sorghum. In Queensland this pest has been found in many samples of commercial seed, and, with the rapid expansion of grain sorghum growing during the past decade, has appeared in first crops in widely scattered, isolated areas.

During 1951-1953, experiments on eliminating the midge from sorghum seed consignments were carried out. Treatments were based on the BHC dusting of seed grain recommended for the control of insect pests of stored grain (McDougall 1951), and the commercial fumigation of grain with carbon bisulphide (Caldwell 1947). A 2 lb. glass jar was used as the unit, and treatments were replicated 10 times. The grain included large numbers of aborted spikelets containing diapause larvae. At examination a specified number of aborted spikelets were selected at random and dissected. During the earlier examinations many of the larvae subjected to fumigation were bleached but otherwise appeared normal: none of these recovered.

Details of treatments and results are given in Tables 1 and 2.

Table 1.

NUMBERS OF LIVING AND DEAD LARVAE.
(1951–52 EXPERIMENT.)

Treatment.	Examination Date.					
	Nov. 8, 1951 (3 months after treatment.)		Apr., 1952 (8 months after treatment.)		Oct., 1952 (11 months after treatment.)	
	Living Larvae†.	Dead Larvae†.	Living Larvae*.	Dead Larvae*.	Living Larvae*.	Dead Larvae*.
BHC dust (0·5% gamma isomer) 3 oz./bus.	30	20	37	25	15	66
Control	23	15	33	23	34	44

†From 100 spikelets per treatment.
*From 200 spikelets per treatment.

Cleaning, grading and chemical dusting of sorghum seed are sufficient for most purposes in Queensland where sorghum midge is widespread. The results of these experiments, however, demonstrate that for quarantine against this pest fumigation with carbon bisulphide is an additional requirement.

Table 2.

NUMBERS OF LIVING AND DEAD LARVAE.
(1953 EXPERIMENT.)

Treatment.	Larvae†.	
	Living.	Dead.
BHC dust (1·0% gamma isomer) 3 oz./bus.	110	24
CS_2(10 lb./1,000 cu. ft.) for 24 hours	Nil	160*
Control	98	14

* At examinations shortly after treatment many of the larvae were bleached: most of these did not dry out or break down until 12 months later.

† From 400 spikelets per treatment, examined on Oct. 13, nine months after treatment.

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INSECTICIDE TRIALS AND NOTES ON CONTROL OF THE POTATO TUBER MOTH IN SOUTH QUEENSLAND

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The standard control for potato tuber moth (*Gnorimoschema operculella* (Zell.)) in the pre-harvest period of potato crops in South Queensland is three (sometimes two) sprays of 1 lb. DDT per acre applied at fortnightly intervals, and hilling the plants 12-14 weeks after planting (May 1952).

In the spring of 1954, a randomised trial with the variety Monak was set out in the Lockyer district to compare the efficacies of DDT, dieldrin and endrin in preventing tuber moth attack. Under the low pest incidence experienced, statistical differences among insecticidal treatments were not obtained, although all were better than the control.

A somewhat similar trial, differing in the addition of a DDD treatment and the use of the variety Sebago, was set out in the spring of 1956. A plot size of 5 rows x 50 feet was used, and sprays were applied by knapsack so as to wet thoroughly all parts of the plants. Adequate irrigation and hilling of plants were carried out. Results were assessed as larval mine counts in a 6-leaved terminal from each of 50 plants per plot; as weights of tops from 15 plants per plot; and as percentages of infested tubers and yields from a complete harvest. Larval mine counts and weights of tops were taken from the three inner rows of each plot.

Table 1.

RESULTS OF 1956 TRIAL.
(*Larval mines per 50 terminals*).

Treatments*.	Pre-treatment (24 Hours Before Spraying).						Pre-harvest.	
	Sep. 12.		Sep. 27.		Oct. 12.		Nov. 5.	
	Trans. Mean.†	Equiv. Mean.	Trans. Mean.†	Equiv. Mean.	Trans. Mean.†	Equiv. Mean.	Trans. Mean.†	Equiv. Mean.
Endrin 0·025% ..	5·11	26·1	2·50	5·8	1·28	1·1	0·93	0·4
Dieldrin 0·05% ..	5·44	29·6	2·53	5·9	1·06	0·6	1·47	1·7
Dieldrin 0·025% ..	5·40	29·2	2·86	7·7	2·01	3·5	1·26	1·1
DDT 0·1% ..	5·32	28·3	2·55	6·0	2·43	5·4	3·20	9·7
DDD 0·1% ..	5·46	29·8	3·56	12·2	2·53	5·9	4·68	21·4
Control	5·57	31·0	5·30	27·6	6·16	37·4	5·86	33·8
Necessary differences for significance 5%	1·08		1·24		·60		·82	
1%	1·49		1·72		·82		1·14	

*Spray strengths as active ingredients.

† $\sqrt{x}$

As a commercial spray programme was used over five-sixths of the experimental area, and proper hilling was carried out, the potentially severe initial infestation was not allowed to develop. Treatments also suppressed larval incidence in the tops. In consequence, no statistical differences among top weights, yields and tuber infestation were expected or recorded. The results of larval mine counts, together with details of insecticide treatments, are given in Table 1.

Though dieldrin and endrin were significantly better than DDT in suppressing larval mining in tops for the last two samplings, this effect was of little practical significance. When the larval mine data for DDT and control treatments in this trial are compared with the data for similar treatments from a comparable trial in the 1950 experiments (May 1952, p. 20), the efficacy of DDT can be more easily appreciated (see Table 2).

Table 2.

LEVELS OF INFESTATION, 1950 AND 1956 TRIALS.

Treatments.	Trial Planted.	Larval Mines per 50 Terminals.				Plots Harvested.
		Pre-treatment.	Pre-treatment.	Pre-treatment.	Prior to Harvest.	
1950 Trial—		Sep. 29	Oct. 13	Nov. 2	Dec. 14	
DDT	Aug. 15	13·5	0·0	0·5	5·5	Dec. 12
Control		13·5	30·0	23·0	216·5	
1956 Trial—		Sep. 12	Sep. 27	Oct. 12.	Nov. 5	
DDT	Aug. 1	28·3	6·0	5·4	9·7	Nov. 12
Control		31·0	27·6	37·4	33·8	

An effective spraying programme was applied to only one-third of the experimental area in the 1950 trial (see May 1952, p. 21) and tops in the control plots were soon reinfested once treatments ceased. Under these circumstances both top weight and yield differences were obtained.

These comparable data indicate that for the control of potato moth, the use of DDT is still sound, and supplement field observations suggesting that most poor commercial control is due primarily to faulty timing and application of the insecticide and/or inadequate hilling.

A schedule of DDT applications is essential for effective control of *Gnorimoschema* in the spring potato crops in southern Queensland (May 1952, p. 26). The pest may be active during a dry autumn also, but normally the spraying of these crops is unnecessary. During the past few years, however, the success of spring spraying with DDT, and sales pressure, have resulted in the wasteful practice of routine autumn spraying becoming fairly

general. This has caused an increase in the status of the potato mite, *Hemitarsonemus latus* (Banks), against which dieldrin may be used as a secondary control measure (Hooper 1957).

Taking into account therefore all important considerations, which include trial results reported in this note, the insecticides for use in the control of the tuber moth should be dieldrin or endrin as required during autumn, and either DDT, dieldrin or endrin in spring. The final choice within these two groups will depend on relative cost and availability.

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